Construction of Extradosed Bridge in the Government Financed Section

EUI-NAM PARK, PM, Incheon Bridge Section 5, Doosan Construction & Engineering corporation
KYUNG-KUK JUNG, GM, Incheon Bridge Section 5, Doosan Construction & Engineering corporation
YOUNG-JUN SHIN, GM, Incheon Bridge Section 5, Doosan Construction & Engineering Corporation.

Abstract
The bridge is located in Incheon city of South Korea. The bridge consists of 3 continuous PSC spans, total length is 308m. Main span was erected by cast-in-place free-cantilever method. The construction work was started in November 2005 and finished in August 2009.

Keywords : Incheon Bridge, FCM, Extradosed Bridge

1. Introduction

Incheon Bridge connecting viaduct contract no. 5 started in November 2005 and finished in August 2009. Extradosed bridged was erected to overpass Ah-am road by cast-in-place FCM method. The contract to construct the bridge was awarded by Korea Expressway Corporation.

2. Outline of the bridge

Type of bridge	3-span continuous deck extradosed bridge
Bridge length	308m
Span arrangement	84m + 140m + 84m
Width of deck	17.10m ~ 19.04m
Main tower	
Type	H-shape concrete tower
Main girder	
Type	PreStressed Concrete girder
Design concrete strength	40MPa
Erection method	cast-in-place Free Cantilever Method
Road and Bridge alignment	
Plane alignment	R=2,400m
Cable	15.7mm x 31ea, applied tensioning force = 4,170kN
Internal tendon	15.2mm x 12ea(upper), 15.2mm x 19ea(lower)

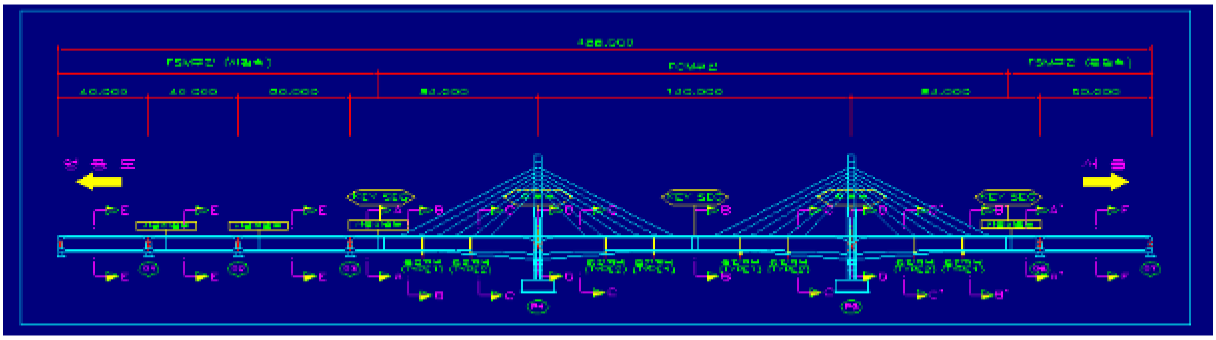


Figure 2.1: General view of extradosed bridge

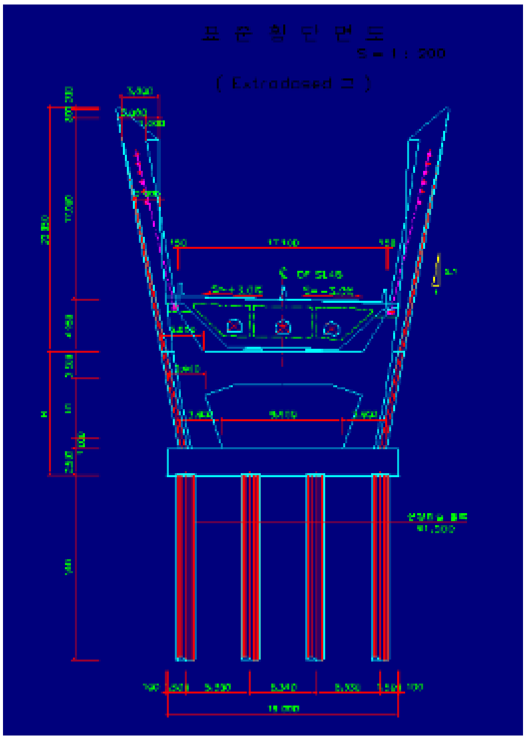


Figure 2.2: General view of tower

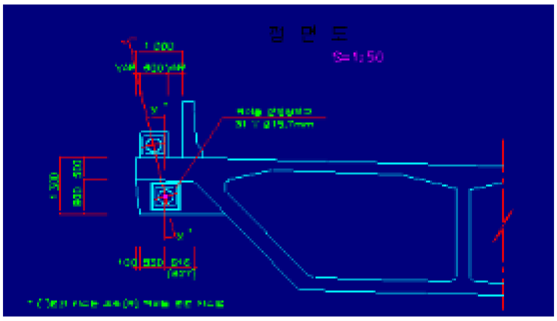


Figure 2.3: Detail of cable anchorage

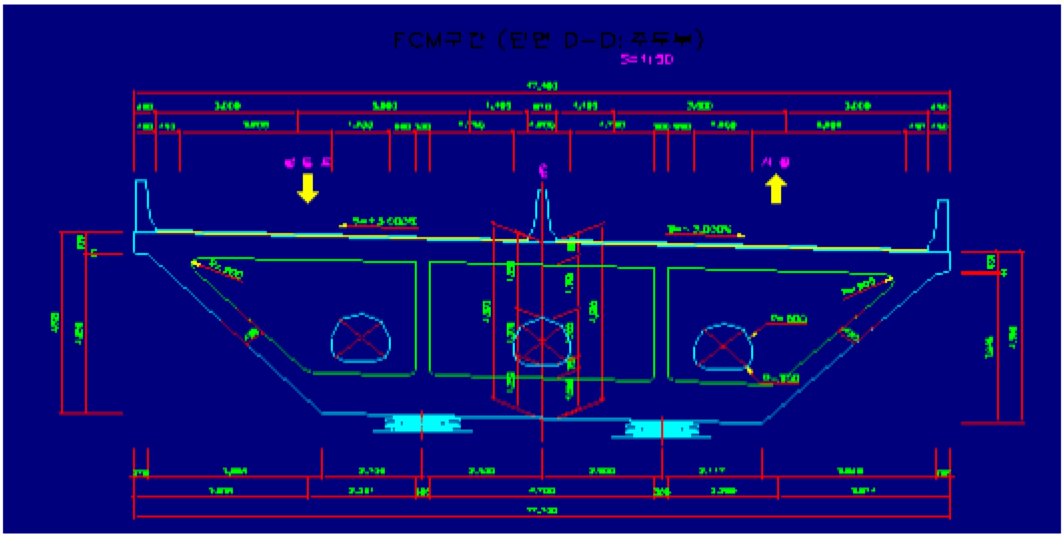


Figure 2.4: Deck cross-section of extradosed bridge

3. Design

3.1. Deck erection method

We proposed cast-in-place free-cantilever method to minimize additional need of casting yard for building girder segments. Camber control and error correction is also possible during cast-in-place erection procedure.

3.2. Bearing support

To minimize the adverse effect of concrete creep, shrinkage and temperature deformation, we applied

bearing system which support superstructure on top of the pylon crossbeam. This provides movability in the longitudinal direction and rotation, flexible to temperature and long-term deformation. Therefore the pylon and footing size can be optimized. Fig 3.1 shows a schematic illustration of two typical support systems.

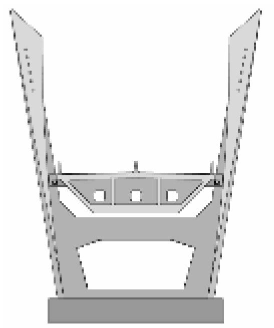
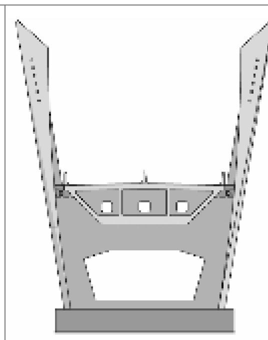
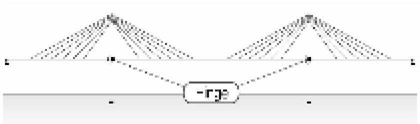
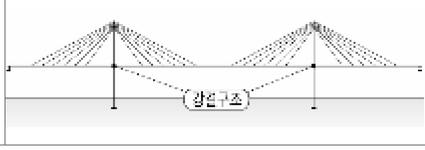
supported by bearings	rigidly connected to pylon
	
	

Figure 3.1: Boundary conditions

3.3. Pylon design

Extradosed bridges have lower pylon height with respect to the cable-stayed bridge. Therefore it shows better performance under seismic activity, smaller cable stress variation due to live load. Cables are installed using separate anchor system to reduce section size and maintenance cost. H-shaped tower chosen to reduce pylon's self-weight and to increase open space to drivers passing under the bridge deck. In respect of load transfer path and structural safety, H-shape structure provides simple load transfer mechanism from girder to footing.

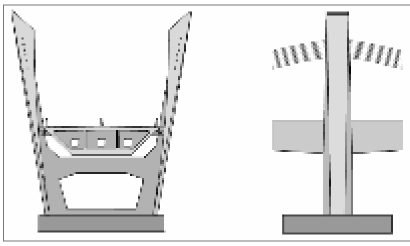
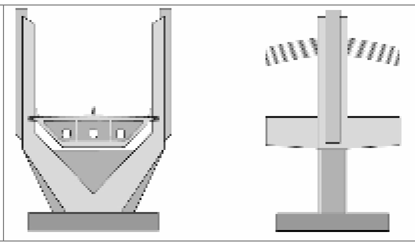
H-shape pylon	Y-shape pylon
	

Figure 3.2: Pylon shapes

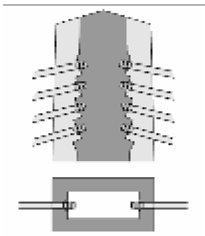
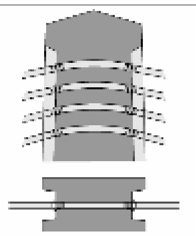
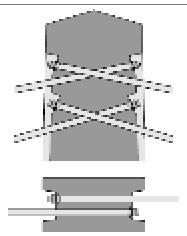
Separate anchor	Saddle type	Inter-cross anchor
		

Figure 3.3: Cable anchoring methods

3.4. Cable design

Semi-fan type and harp type is generally considered for typical extradosed bridges. Semi-fan type is chosen to increase vertical component of cable tensile force, therefore overall structures's stiffness against vertical live loads will increase, which let the girder to be designed economically. Semi-fan type is effective to have smaller axial force in girder and negative bending moment near support area. Harp type layout has smaller vertical cable tension. In this case, girder and cable will be required to have more stiffness than semi-fan type.

It was decided that bonded-stranded cables applied to stay cables. The cables were particularly required to have advanced field precision management of bridge shape because the allowable tolerance of girder camber upon completion for the cable-stayed span is restricted. The cable were particularly required to show good maintenance and easy to adjust the cable tension force after installed. Zinc-coated bonded-strands are required to reduce maintenance cost. However saddle type system is difficult to replace or adjust tension after installation completed. Epoxy-coated strands are generally chosen for saddle type anchor system because the cables have better bonding properties.

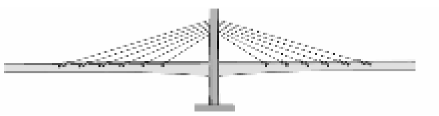
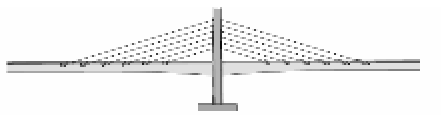
Semi Fan type	Harp type
	

Figure 3.4: Typical cable layouts

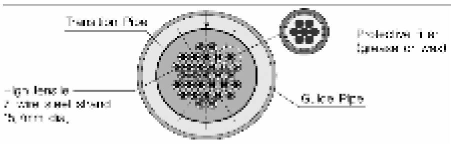
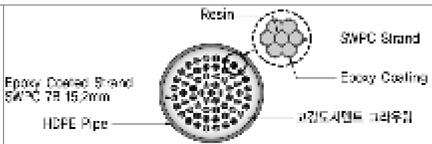
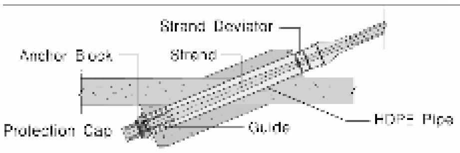
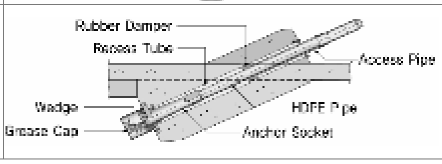
Bonded Strand	Epoxy Coated Strand
	
	

Figure 3.5: Types of cable strands

4. Construction

4.1 Construction work plan

In-situ concrete piles were applied to support heavy tower of bridge's main span. After completion of tower, temporary bent structure assembled to erect pylon pier table, which is used to provide enough space to place form-traveller. Girders for main and side span are erected using form-traveller segment-by-segment. To close main span, key-segment is placed after all cables and segments are properly in place. The entire work process for the superstructure is shown in Table. 4.2

Table 4.1 Construction schedule of extradosed bridge

	'06	'07	'08	'09
Pylons				
Pier Tables				
Erect girderSegments				
Key Segment				
Pavement				

Table 4.2 Construction schedule of extradosed bridge(superstructure part)

Category	day 1	day 2	day 3	day 4	day 5	day 6	day 7	day 8	day 9	day 10	day 11	day 12	day 13	day 14	day 15
F/T Setting															
1st camber set															
Deck formwork															
Rebar assemble															
Adjust camber															
Cast concrete															
Remove deck formwork															
Tendon jacking															

tendon															
Install the cable															

4.2 Pylon construction

Each of two pylons has divided into 9 and 8 blocks. Climbing-form method was adopted to cast concrete with 3~6m height segments. Climbing-form is frequently used for building tall structures having prismatic and proportionally changing sections like piers. It is easy and fast to assemble and disassemble with system form. Tie-rod can resist vertical and horizontal force acting on form faces. Climbing-form itself provides work space for rebar work, attaching and removing forms. Such kind of specially designed form prevents large deformation of formwork during concrete casting, therefore advanced precision management is possible. One lot of segment can be maximum 6.0m, however 4.0m is applied for work efficiency.

Figure 4.1: Pylon and pier table

4.3 Camber control

It is important to control the camber to enhance the maintenance, driving comfort during service life time. Deck finish level of concrete bridge built with balancing method can be lower than expected by concrete creep and shrinkage. This kind of deformation can be removed by construction camber.

Figure 4.2: Form traveller

4.3.1 Factors of camber

a. loads : concrete self-weight, form traveller(F/T) weight, prestressing, temperature, erection load
b. PS tendon property : elastic modulus, relaxation
c. concrete property : elastic modulus, creep and shrinkage

4.3.2 Factors not included in camber model

a. deformation of F/T

F/T itself deform by any kind of load during erection. The amount of camber by such kind of non-structural deformation is not included in camber calculation. Therefore we should estimate before erection work started and adjust camber during construction. However, the estimation is based on the ideal assumption, actual field value is different from calculation result. Therefore the actual amount of displacement should be carefully monitored and corrected at early stage of 2~5 segments erection. When F/T assembled, there exist the gaps between connection parts that make additional displacement. This value generally will be assumed 20mm and adjusted at first 1 or 2 segment erections. As the segment loaded, F/T rotates with the deformation of bars which resist moment induced by eccentricity of wet concrete load to F/T gravity center. This should be removed by additional prestressing.
The initial displacement of F/T assumed to be zero. Therefore, we have to include the presetted level of F/T in actual camber.

b. additional camber

Prestressing of tendon at section bottom, long-term deformation by creep & shrinkage and unexpected vertical displacement should be included in camber. Additional camber is applied to compensate such kind of additional displacement and distributed at each segment erection stage. Generally the amount of additional camber at each stage is 50% of difference between initial segment level and target geometry of segment. After all the erection completed, creep and shrinkage deformation is supposed to increase up to final finish level. 50% of long-term displacement is generally included in the additional camber value.

c. error correction

Unexpected error between calculation and field value will be distributed over 2 or 3 segment erection to adjust camber. Monitoring camber line and measurement conducted as early as at the same time. Error will be distributed in several stage of erection. If there is change of sectional properties, measurement has to be done carefully.

5. Conclusion

Recently in Korea, extradosed bridge is competitive with other types of bridges having similar span length. We hope that the experience through the construction of this extradosed bridge is to be a successful example of technical development for domestic engineers.

fig. 5.1 view of E/D bridge

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